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(19) (CA) **APPLICATION FOR CANADIAN PATENT** (12)

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(54) Process for Producing a Metal Melt

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Notice: This application is as filed and may therefore contain an incomplete specification.

ABSTRACT OF THE DISCLOSURE:

In a process for producing a metal melt, in particular, a steel melt, in an electric arc furnace, the bath surface is covered by a foamed slag during the flat bath period(s). In order to ensure the advantages of an electric arc enveloped by foamed slag over an extended period of time at expenditures as low as possible, level measuring of the layer height of a slag is carried out several times during a furnace heat. Foamed slag enveloping an electric arc generated by at least one electrode is formed by blowing solids, gases or a mixture of solids and gases into or onto the slag or the metal melt. The layer height of the foamed slag is dimensioned such that the foamed slag at least extends over all of the electric arc, a number of advantages, thus, being, utilized to the optimum degree.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A process for producing a metal melt, such as a steel melt, in an electric arc furnace accommodating a bath of metal melt having a bath surface, by covering said bath surface with foamed slag over a foamed slag layer height during a flat bath period, which process comprises the steps of

providing at least one electrode for forming an electric arc,

providing a slag having a slag layer height on said bath surface,

carrying out level measuring of said slag layer height several times during a furnace heat,

forming foamed slag by blowing one of solids, gases and a mixture of solids and gases at least one of into and onto one of said slag and said metal melt so as to envelop said electric arc, and

dimensioning said foamed slag layer height such that said foamed slag at least extends over all of said electric arc.

2. A process as set forth in claim 1, further comprising

producing a measuring signal by said level measuring,

providing a control system for processing said measuring signal as a controlled variable,

which control system includes a manipulated variable,

said manipulated variable influencing said blowing of at least one of solids, gases and a mixture of solids and gases at least one of into and onto one of said slag and said metal melt, thus also influencing said foamed slag layer height.

3. A process as set forth in claim 1, wherein said level measuring is carried out continuously.

4. A process as set forth in claim 1, wherein sound emissions derived from said electric arc furnace are used for carrying out said level measuring.

5. A process as set forth in claim 1, wherein an optical measuring method is used for carrying out said level measuring.

6. A process as set forth in claim 5, wherein said optical measuring method comprises optical high-temperature measuring.

7. A process as set forth in claim 1, wherein electric operational parameters of said electric arc furnace are used for carrying out said level measuring.

8. A process as set forth in claim 7, wherein said electric operational parameters comprise directly measured characteristic quantities, such as current and harmonic waves.

9. A process as set forth in claim 7, wherein said electric operational parameters comprise characteristic quantities, such as current and harmonic waves, determined by analysis.

10. A process as set forth in claim 7, wherein said electric operational parameters comprise directly measured characteristic quantities and characteristic quantities determined by analysis.

11. A process as set forth in claim 1, wherein said electrode forming said electric arc is a self-consuming graphite electrode having a central longitudinal recess and said at least one of solids and gases and mixtures of solids and gases is introduced into said electric arc through said central longitudinal recess of said self-consuming graphite electrode.

12. A process as set forth in claim 1, wherein said solids used for forming said foamed slag are selected from the group consisting of coal, coke, wood, iron carbide, directly reduced iron, hot-briquetted iron, ore, filter dusts, scales, dried and disintegrated sludge, slag formers.

13. A process as set forth in claim 12, wherein said slag formers are selected from the group consisting of at least lime, limestone, dolomite and fluorspar.

14. A process as set forth in claim 12, wherein said solids are used individually.

15. A process as set forth in claim 12, wherein said solids are used in combination.

16. A process as set forth in claim 1, wherein said gases used for forming said foamed slag are selected from the group consisting of O_2, air, N_2, Ar, natural gas and other hydrocarbons, H_2O (steam), CO_2.

17. A process as set forth in claim 16, wherein said gases are used individually.

18. A process as set forth in claim 16, wherein said gases are used in combination.

19. An arrangement for producing a metal melt, such as a steel melt, forming a bath of metal melt having a bath surface, by covering said bath surface with foamed slag during a flat bath period, which arrangement comprises

an electric arc furnace including at least one electrode as well as a furnace vessel accommodating said bath of metal melt and a slag present on said metal melt over a slag layer height, said at least one electrode being adapted to form an electric arc,

a level measuring means configured to measure said slag layer height,

a control system coupled with said level measuring means,

at least one supply means adapted to supply at least one of solids, gases and a mixture of solids and gases at least one of into and onto one of said slag and said metal melt so as to form foamed slag over a foamed slag layer height at least extending over all of said electric arc, and

a control element adapted to connect said control system with said supply means.

20. An arrangement as set forth in claim 19, wherein said level measuring means is comprised of a sound measuring means.

21. An arrangement as set forth in claim 19, wherein said level measuring means is comprised of a high-temperature measuring means.

22. An arrangement as set forth in claim 21, wherein said high-temperature measuring means is comprised of a high-temperature video camera.

23. An arrangement as set forth in claim 21, wherein said high-temperature measuring means is comprised of a high-temperature radar means.

24. An arrangement as set forth in claim 19, further comprising an offgas seizure means provided at said electric arc furnace, said level measuring means being installed in said offgas seizure means.

25. An arrangement as set forth in claim 19, wherein said level measuring means is provided at said furnace vessel above said foamed slag.

26. An arrangement as set forth in claim 19, wherein said level measuring means is provided at a distance from, and outside of, said electric arc furnace.

27. An arrangement as set forth in claim 19, wherein at least one electrode having a central longitudinal recess is provided and a duct means adapted to supply at least one of fine-grain solids and gases enters into said central longitudinal recess of said electrode.

28. An arrangement as set forth in claim 19, wherein said electric arc furnace is designed as an alternating current electric arc furnace.

29. An arrangement as set forth in claim 19, wherein said electric arc furnace is designed as a direct current electric arc furnace.

The invention relates to a process for the production of a metal melt, in particular, of a steel melt, in an electric arc furnace, wherein the bath surface is covered by a foamed slag during the flat bath period(s), as well as an arrangement for carrying out the process.

In the production of steel by aid of electric energy in an electric arc furnace, the electric arc, if desired, several electric arcs, furnish(es) the major portion of the process heat required. With discontinuous processes, foamed slag operation, which is known per se, is sought in practice after the partial and/or complete formation of the socalled flat bath, which forms, for instance, after scrap or sponge iron has been melted to the major extent and approximately corresponds to one third of the duration of a heat.

From US-A-4,447,265 it is known to completely surround or envelop the electric arc with the foamy slag. The advantages of such slag control are as follows:

- Increase in the thermal efficiency of the electric energy supplied and reduction of the electric energy consumption;
- possibility of operating with long arcs (high voltages at relatively low intensities) without thereby causing too much thermal load on the furnace walls and on the furnace lid - hence follows less refractory wear; also the electrodes are stressed to a lesser degree;
- increase in the productivity of the plant because of the shortened melting time attainable under otherwise equal conditions;
- lowering of the electrode consumption;
- less annoyance caused by noise in the environment of the furnace;
- lower N-contents in the steel;
- enhanced conditions for the blowing in of solids through hollow electrode(s).

Foamed slag operation is of particular advantage with

- electric arc furnace melting (direct or alternating current) with extended flat bath periods, such as, e.g., when charging directly reduced iron (sponge iron) and/or fine-grain iron carriers (sponge iron dusts, iron carbide, ore, filter dusts, etc) as well as
- electric arc furnace melting with direct current using one or several electric arcs because of the basically larger length of the electric arc(s) as compared to alternating current electric arcs, and
- continuously operating processes in which energy is supplied via electric arcs and coolant is supplied over long periods of time in substantial flat bath operation.

It is known (cf. Met. Trans. B 20, 1989, No. 4, 509-514 (cn), Kimihisa Ito et al., "Study on the Foaming of CaO-SiO_2-FeO Slags: Part I. Foaming Parameters and Experimental Results"; Met. Trans. B 20, 1989, No. 4, 515-521 (cn), Kimihisa Ito et al., "Study on the Foaming of CaO-SiO_2-FeO Slags: Part II. Dimensional Analysis and Foaming in Iron and Steelmaking Processes") that the formation of foam with steel production slags of the basic system CaO-SiO_2-FeO_n with certain portions of MgO, Al_2O_3, Cr_2O_3, MnO, P_2O_5, S, CaF_2 etc. is determined by the following influencing variables:

- the steel bath temperature
- the speed and site of CO/CO_2 gas formation
- the physicochemical properties of the slag as a function of its composition (viscosity, surface tension slag/gas, interfacial tension slag/metal, basicity, iron oxide content and activity, type and quantitative ratio of the slag phases, etc.).

Slag foaming is promoted by a lower bath temperature and an increasing slag viscosity both in the homogenous and in the heterogenous ranges. Therein, the content of iron oxide plays a particular role, since FeO_n on the one hand liquefies the slag with an increasing portion, thus counteracting the formation of foamed slag, yet on the other

hand constitutes an important oxygen supplier for the formation of CO, thus promoting this important prerequisite of slag foaming. Consequently, ranges with strongly varying foaming behaviors of the slag will result in the above-mentioned quasi three-component system (cf. Stahl u. Eisen 106 (1986), No. 11, 625-630, Dieter Ameling et al. "Untersuchungen zur Schaumschlackenbildung im Elektrolichtbogenofen").

In common steelworks practice, foamed slag operation preferably is influenced by cage-charging coal, by adding lumpy coal through the lid (or through the slag door) and/or by blowing in fine coal through lances (tuyeres) of various designs, the utilization of coal in the last case being substantially better, additionally leading to a more rapid and more intense foam formation. The reaction of the carbon with the dissolved oxygen in the steel bath, the iron oxide of the slag as well as the gaseous oxygen additionally blown in through lances (tuyeres) produces an intensive CO/CO_2 formation that causes the slag to foam.

Since the bath conditions and, thus, the influencing variables of the foamed slag formation constantly change during the flat bath period not only slightly, but to even larger degrees, it is difficult to ensure a foamed slag always having a sufficient layer height over a longer period of time. Therefore, the advantages of foamed slag operation pointed out above can be utilized to a slight extent only, i.e., if at all, only over a short interval of the flat bath period.

According to US-A-4,447,265, a slag composition is indicated which yields a foamed slag enveloping long electric arcs, yet there is the danger with constantly changing bath conditions, of overfoaming, on the one hand, or of too small a height of the foamed slag, on the other hand.

Therefore, the invention has as its object to provide a process of the initially defined kind as well as an arrangement for carrying out such process, which render feasible the advantages attainable by an electric arc enveloped by foamed slag over an extended

period of time, i.e., if possible, over almost the entire flat bath period, wherein expenditures in terms of personnel and material are to be kept as low as possible, i.e., solids and/or gases charged are required in very slight amounts only and investments costs incur to a slight extent only.

With a process of the initially defined kind, this object is achieved in that level measuring of the layer height of a slag is carried out several times during a furnace heat, and a foamed slag enveloping an electric arc generated by at least one electrode is formed by blowing solids, gases or a mixture of solids and gases into or onto the slag or the metal melt, the layer height of which foamed slag is dimensioned such that the foamed slag at least extends over all of the electric arc.

For purposes of automation of the process, a measuring signal produced by level measuring advantageously is processed as a controlled variable in a control system, whose manipulated variable influences the blowing of solids, gases or a mixture of solids and gases into and/or onto the slag or the metal melt and hence the layer height of the foamed slag, level measuring suitably being carried out continuously.

According to a preferred variant, sound emissions derived from the electric arc furnace are used for level measuring.

Another preferred variant is characterized in that electric operational parameters of the electric arc furnace, i.e., characteristic quantities (current, upper harmonic waves) measured directly and/or determined by analysis are used for level measuring.

For particular circumstances, it may be of advantage if an optical measuring method, in particular, an optical high-temperature measuring method or a radar device, is used for level measuring.

It is particularly advantageous if solids and/or gases and/or mixtures of solids and gases are introduced into the electric arc of a self-consuming graphite electrode via a central longitudinal recess of the graphite electrode. Thereby, the formation of the

foamed slag occurs on that site on which it is required in the first place, i.e., in the immediate vicinity of the electric arc such that the ideal condition, i.e., the envelopment of the electric arc, can be reached within a very short span of time and subsequent control becomes effective at once.

Preferably, the following solids are used for the formation of foamed slag, either individully or several in combination: coal, coke, wood, iron carbide, directly reduced iron (DRI), hot-briquetted iron (HRI), ore, filter dusts, scales, dried and disintegrated sludge, slag formers (lime, limestone, dolomite, fluorspar, etc.).

Suitably, the following gases are used for the formation of foamed slag, either individually or several in combination: O_2, air, N_2, Ar, natural gas and other hydrocarbons, H_2O (steam), CO_2.

An arrangement for carrying out the process of the invention is characterized by the combination of the following characteristic features:

- an electric arc furnace comprising at least one electrode,
- a level measuring means for measuring the layer height of a foamed slag present on a metal melt
- a control system coupled with the level measuring means,
- at least one supply means for supplying solids and/or gases and/or solids-gas mixtures, the control system being coupled with the supply means via a control element.

According to an embodiment that is very simple to realize in terms of construction, the level measuring means advantageously is comprised of a sound measuring means.

However, the level measuring means also may be comprised of a high-temperature measuring means, such as a high-temperature video camera or a high-temperature radar.

Advantageously, the level measuring means is installed in the offgas seizure means of the electric arc furnace or in the furnace vessel above the foamed slag.

If a level measuring means is to be provided later on at an already existing electric arc furnace, the level measuring means advantageously is arranged at a distance from, and outside of, the electric arc furnace, thus minimizing modification work at the electric arc furnace.

For influencing the layer height of the foamed slag, at least one electrode having a central longitudinal recess into which a duct supplying fine-grain solids and/or gases enters is advantageously provided.

The invention may be realized with a particular advantage in an electric arc furnace designed as a direct current electric arc furnace, because in a direct current arc furnace particularly long electric arcs occur, for which the envelopment by foamed slag according to processes already known is feasible only insufficiently over an extended period of time.

In the following, the invention will be explained in more detail by way of an exemplary embodiment illustrated in the drawing, wherein:

Fig. 1 is a schematic view of a partially sectioned arrangement configured in accordance with the invention, and

Fig. 2 illustrates the process according to the invention in diagrammatic form.

A self-consuming graphite electrode 3 projects centrally into an electric arc furnace 1 from top through its lid 2, its electric arc 4 burning against a steel melt 6 covering the bottom 5 of the electric arc furnace 1. A counter electrode 7 is arranged in the bottom 5. The embodiment illustrated is a direct current electric arc furnace comprising just one electrode. However, it would also be possible to provide several self-consuming graphite electrodes 3 - as is indicated by dot-and-dash lines, which may be operated with alternating or rotary current.

On the steel bath surface 8, there is a layer of foamed slag 9 having a predetermined layer height 10. The self-consuming graphite electrode 3 is designed as a hollow

electrode. Through its internal central longitudinal recess 11, fine-grain solids and/or gases or mixtures of solids and gases can be supplied via a duct 12, then immediately getting into the electric arc 4. The lid of the electric arc furnace 1, furthermore, includes a lid opening 13, through which lumpy solids supplied through duct 14 can be charged into the interior 15 of the electric arc furnace.

Through the side wall 16 of the electric arc furnce 1, one or several lances 17 project into the interior 15 of the electric arc furnace 1, which lances are displaceably or rigidly arranged relative to the latter and either are protected by cooling water or cooling gas or - if not protected - are self-consuming. The lances 17 partially also might be conducted through the furnace lid and, moreover, might be replaced with lateral or lid tuyeres. The lances 17 also may serve to introduce fine-grain solids and/or gases or solids-gas mixtures. The supply of such substances is effected through ducts 18. Such mixtures and solids and/or gases also might be introduced through bottom tuyeres 19 or bottom flushing bricks (only gases) fed by separate ducts 20.

Among others, the following materials may be employed as solids and gases responsible for the formation of a foamed slag:

- solids (fine-grain and/or lumpy):

  coal, coke, wood, iron carbide, directly reduced iron (DRI), hot-briquetted iron (HRI), ore, filter dusts, scales, dried and disintegrated sludge, slag formers (lime, limestone, dolomite, fluorspar, etc.) as well as solids mixtures

- gases:

  O_2, air, N_2, Ar, natural gas and other hydrocarbons, H_2O (steam), CO_2 as well as gas mixtures.

The offgas forming in the interior 15 of the electric arc furnace 1 is conveyed to a filtering plant (not illustrated) through an offgas duct 21. In this offgas duct, there is incorporated a level measuring means 22, which, in the exemplary embodiment

illustrated, is designed as a microphone, which takes up the noise produced by the electric arc 4 (the sound waves being represented by 23), transmitting it to a control system 24 as a measuring signal. This control system comprises an evaluation unit 25, in which, at first, the entire frequency spectrum of the furnace noise and, after this, the noise level P_{meas} within a frequency range characteristic of slag foaming are detected.

The thus obtained measured noise level P_{meas} subsequently is compared with a reference noise level P_{set} already known for the electric arc furnace 1 within the same frequency range. In doing so, the reference noise level P_{set} corresponds to the foamed slag operation sought - e.g., an operation in which the electric arc 4 is completely enveloped by the foamed slag 9.

The result of the comparison of the reference noise level P_{set} with the measured noise level P_{meas} is transmitted as a correcting factor P_{corr} to a controller 26, which, in turn, automatically takes the measures that are required to raise or lower the layer height 10 of the foamed slag 9 to a predetermined value by controlling the controlling elements 27 dosing the solids and/or gases and/or mixtures of solids and gases. Preferably, this is effected automatically; however, it would also be possible to send an appropriate message to the operator on the furnace stand, whereupon the latter brings the controlling elements 27 into appropriate positions.

As is indicated by broken lines in Fig. 1, the microphone 22 also could be arranged outside of the electric arc furnace 1 at a lateral distance therefrom. Instead of the microphone 22, a high-temperature measuring means, which, for instance, is comprised of a high-temperature video camera or a high-temperature radar, could be installed in the offgas duct 21 or at any suitable point at the furnace.

According to a further variant, the electric operational parameters voltage (V) and intensity (I) of the electric arc furnace are applied for level measuring. They are constantly detected and transmitted to an evaluation unit 25. In the instant case, the

evaluation unit 25 incorporates a special DSP (digital system processor) transformer rapidly detecting the effective values of the electric operational parameters and a current harmonic spectrum. The harmonic spectrum or a partial spectrum based on the former and characteristic of the level measurement serves as a measurable variable P_{meas}. It is subsequently used, with a preadjusted reference harmonic spectrum P_{set}, to generate the correction factor P_{corr} for the controller 26 - in a manner similar to sound level measuring.

According to the invention, the measurement/control of the height of the foamed slag also may be effected by a combination of several variants (e.g., noise level measuring and current harmonic wave analysis).

In the following, an example of the production of a steel melt will be described, the steel melt having been melted in a 72-ton alternating current electric arc furnace of an arrangement according to Fig. 1. The 72-ton alternating current electric arc furnace was equipped with three electrodes as indicated by dot-and-dash lines in Fig. 1.

The production of the steel melt 6 was effected under the following operational conditions observed during the flat bath period:

- Bath temperature
  - at the beginning of flat bath period: 1550°C
  - at the end of flat bath period (= beginning of tapping): 1640°C
- Steel melt: about 70 tons
  - [%C] at the beginning of flat bath period: 0,21
  - [%C] at the end of flat bath period: 0,09
- Slag: about 6 tons
  - (% FeO_n) at the beginning of flat bath period: 12
  - (% FeO_n) at the end of flat bath period: 17
  - (% CaO)/(% SiO_2) at the beginning of flat bath period: 2.1

- $(\% CaO)/(\% SiO_2)$ at the end of flat bath period: 2.2
- Duration of flat bath period: 12 min
- Electric arc length: about 250 mm

The microphone 22 that served as a sound detector was arranged on a holding means at a distance of approximately 3 m from the electric arc furnace 1.

From preliminary tests, a frequency range of 100 to 500 Hz was determined as being characteristic of the formation of foamed slag in the electric arc furnace 1 such that both the measuring sound level and the reference sound level (adjusted to about 300 mm slag height 10 of the foamed slag 9) were determined for this frequency range.

From the change in the ratio of the measuring sound level P_{meas} to the reference sound level P_{set} during the time of charging (Fig. 2), the layer height 10 of the foamed slag and the degree of envelopment of the electric arcs 4 (in respect of the reference condition chosen) and hence the measures to be taken for controlling the foamed slag could be directly concluded.

For controlling the formation of the foamed slag, fine-grain coal (grain size < 2 mm) was blown in by N_2 carrier gas (about 0.1 Nm^3 N_2/kg coal) in portions through the hollow electrode 3. During the entire flat bath period, O_2 was constantly blown into the foamed slag 9 through the water-cooled lances 17 (about 21 Nm^3 O_2/min); yet, no lumpy solids - including slag formers - were added through the lid opening 13. N_2 (Ar) and a slight amount of natural gas were injected into the metal melt 6 through the bottom tuyeres 19.

At first, unfoamed slag was present on the steel bath surface 8. From the second minute of the flat bath period - i.e., two minutes after the charge had been melted completely - controlling was started, 11 kg of coal having been supplied through the hollow electrode 3 for about 2 minutes. Simultaneously with the supply of coal, oxygen was injected into the interior 15 of the electric arc furnace through the water-cooled

lance at an amount of 21 Nm^3 O_2/min almost till the end of the flat bath period, i.e., closely before tapping was started. From Fig. 2 it is apparent that the layer height 10 of the foamed slag 9, at first, had assumed a value above the ideal value, levelling out at the ideal value, i.e., at the sought value of 300 mm, afterwards. In order to keep the layer height 10 of the foamed slag 9 constant in the following, another 12 kg of coal were introduced over a period of time of approximately 6 min through the hollow electrode 3 during the second half of the flat bath period, which lasted for a total of 12 min.

As is apparent from Fig. 2, sufficient envelopment of the electric arc 4 could be ensured, starting with the control of the layer height of the foamed slag from minute 2, over the major period of time during which controlling was effected, only slight amounts of solids and gases having had to be supplied.

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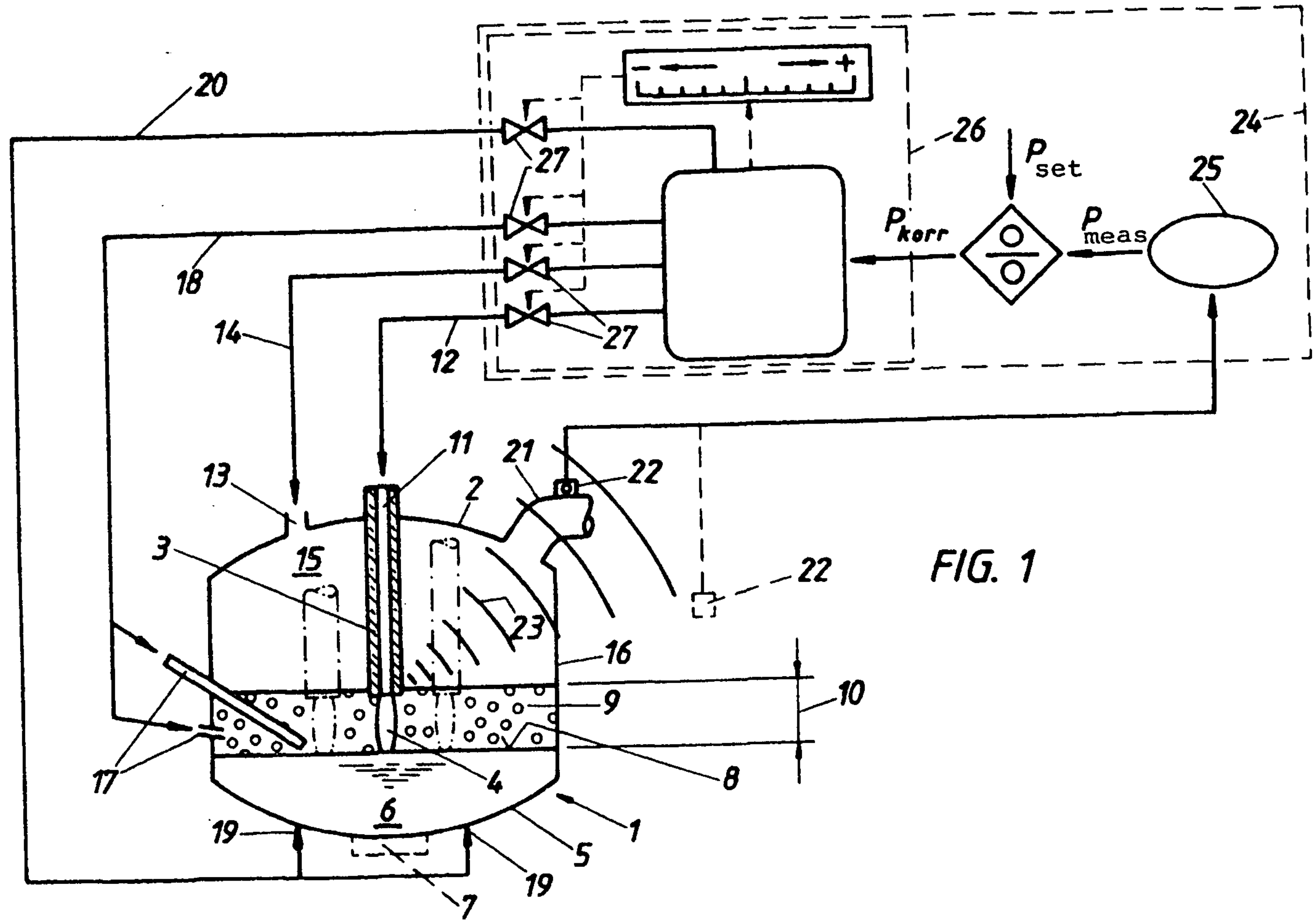

FIG. 1

PATENT AGENTS

Awabey Ogilvy Renault

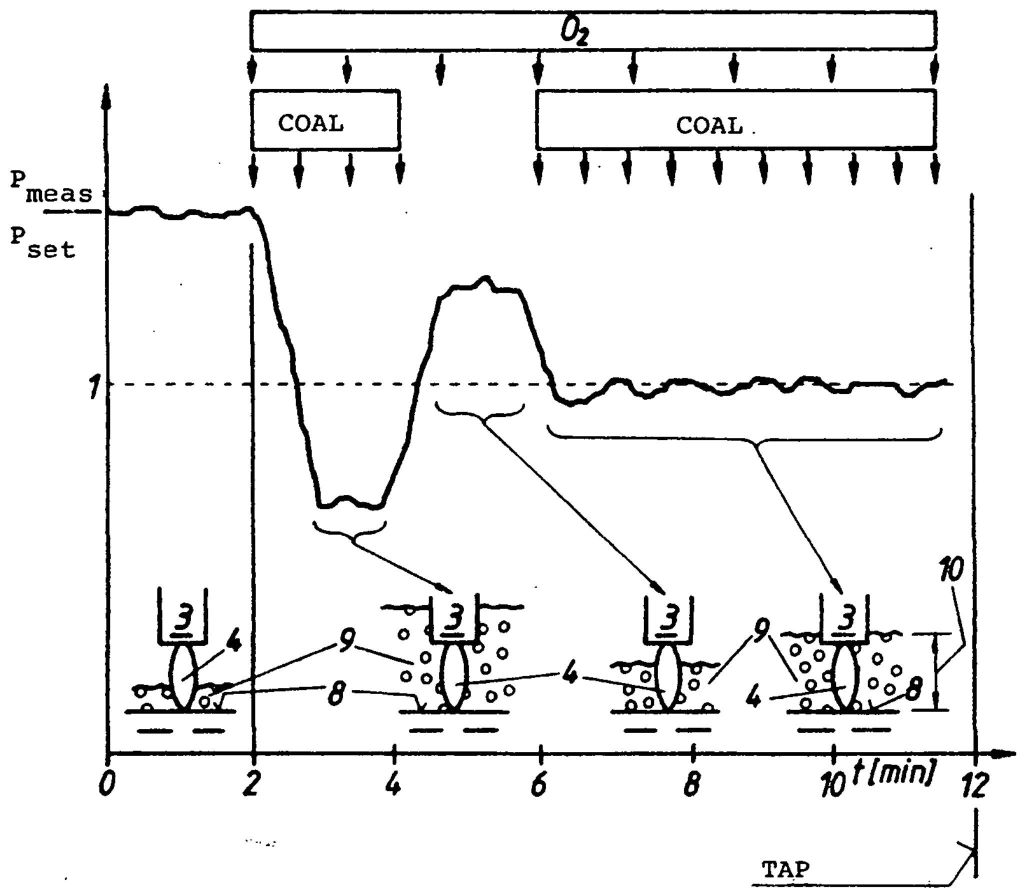

FIG. 2

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Swabey Ogilvy Renault